AFRL-RZ-WP-TP-2012-0100

CORRELATION OF AC LOSS DATA FROM MAGNETIC SUSCEPTIBILITY MEASUREMENTS WITH YBCO FILM QUALITY (POSTPRINT)

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FEBRUARY 2012

AIR FORCE RESEARCH LABORATORY
PROPULSION DIRECTORATE
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7251
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
February 2012	Conference Paper Postprint	01 January 2002 – 01 January 2004

4. TITLE AND SUBTITLE
CORRELATION OF AC LOSS DATA FROM MAGNETIC SUSCEPTIBILITY MEASUREMENTS WITH YBCO FILM QUALITY (POSTPRINT)

5a. CONTRACT NUMBER
In-house

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
62203F

6. AUTHOR(S)
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5d. PROJECT NUMBER
3145

5e. TASK NUMBER
32

5f. WORK UNIT NUMBER
314532Z9

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Mechanical Energy Conversion Branch (AFRL/RZPG)
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8. PERFORMING ORGANIZATION REPORT NUMBER
AFRL-RZ-WP-TP-2012-0100

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory
Propulsion Directorate
Wright-Patterson Air Force Base, OH 45433-7251
Air Force Materiel Command
United States Air Force

10. SPONSORING/MONITORING AGENCY ACRONYM(S)
AFRL/RZPG

11. SPONSORING/MONITORING AGENCY REPORT NUMBER(S)
AFRL-RZ-WP-TP-2012-0100

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
Conference paper published in the proceedings of the *Materials Research Society Symposium*, Vol. EXS-3, 2004. © 2004 Materials Research Society. The U.S. Government is joint author of the work and has the right to use, modify, reproduce, release, perform, display, or disclose the work. Work on this effort was completed in 2004.

PA Case Number: ASC-03-1852; Clearance Date: 06 Dec 2004.

14. ABSTRACT
It has been previously suggested that with spreading of the temperature-dependent ac susceptibility curves with increasing applied magnetic field, the quality of the YBCO film generally decreases. However, a documented study of this correlation to current transport properties using the imaginary or loss component of ac susceptibility data is not available. A detailed study was performed using the available data on YBCO films produced by pulsed laser deposition on different substrates which included LAO, STO, and buffered metallic substrates. The ΔT between the temperatures at which the maxima in the ac loss occurs for 0.025 and 2.2 Oe applied magnetic fields (peak to peak of χ") was determined. In addition, the full-width at half-maximum (FWHM) of the χ" vs. T width (ΔT) of the loss component of susceptibility data was determined for the 0.025 Oe magnetic field data and the 2.2 Oe magnetic field data for comparison. A correlation on this level may prove useful as a preliminary screen of YBCO film quality, especially as good YBCO films can now be routinely made.

15. SUBJECT TERMS
magnetic, substrates, films, component, deposition, laser, pulsed, buffered, metallic, peak, correlation, preliminary

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT:	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON (Monitor)
a. REPORT	b. ABSTRACT	c. THIS PAGE			Timothy J. Haugan
Unclassified	Unclassified	Unclassified	SAR	10	19b. TELEPHONE NUMBER *(Include Area Code)* N/A

Correlation of AC Loss Data from Magnetic Susceptibility Measurements with YBCO Film Quality

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ABSTRACT

It has been previously suggested that with spreading of the temperature-dependent ac susceptibility curves with increasing applied magnetic field, the quality of the YBCO film generally decreases. However, a documented study of this correlation to current transport properties using the imaginary or loss component of ac susceptibility data is not available. A detailed study was performed using the available data on YBCO films produced by pulsed laser deposition on different substrates which included LAO, STO, and buffered metallic substrates. The ΔT between the temperatures at which the maxima in the ac loss occurs for 0.025 and 2.2 Oe applied magnetic fields (peak to peak of χ'') was determined. In addition, the full-width at half-maximum (FWHM) of the χ'' vs. T width (ΔT) of the loss component of susceptibility data was determined for the 0.025 Oe magnetic field data and the 2.2 Oe magnetic field data for comparison. A correlation on this level may prove useful as a preliminary screen of YBCO film quality, especially as good YBCO films can now be routinely made.

INTRODUCTION

For high temperature superconducting (HTS) films a sharp transition in the resistivity vs. temperature curve at T_c, as well as a T_c close to the maximum value for the given film, are typically desired for better quality films. In addition to this it has been noted that the quality of HTS film generally lowers with spreading of the temperature-dependent ac susceptibility curves as the applied magnetic field increases [1]. However, a documented study of the potential correlation between the current carrying properties of HTS films and this loss component of ac susceptibility data has not been published. Without a systematic study, it is unclear how effective this correlation actually is. This paper presents initial results comparing analysis of the ac loss data from magnetic susceptibility measurements to the critical current density (J_c) as determined by current transport measurements. It consists of a detailed study performed using the available data within our research group on $YBa_2Cu_3O_{7-d}$ (YBCO) films and $YBa_2Cu_3O_{7-d}/Y_2BaCuO_{7-d}$ (Y123/Y211) composite films previously developed [2-4].

EXPERIMENTAL DETAILS

YBCO films and Y123/Y211 composite films were produced by pulsed laser deposition described elsewhere [2-4]. The laser used was either a LPX 305i model or LPX300 model Lambda Physik excimer laser operating at the KrF, 248 nm, wavelength. Substrates included LaAlO3 (100) and SrTiO3 (100) single crystal substrates as well as buffered (CeO_2/YSZ/CeO_2)

textured Ni substrates. The oxygen deposition pressure was 300 mTorr kept constant in the chamber using a downstream throttle-valve control as O_2 gas flowed into the chamber during growth. Substrates were attached to the heater using a thin layer of colloidal Ag paint and heated to ~ 785 °C. After deposition, films were cooled in O_2 for post-deposition oxygenation. Critical currents were measured using macrobridges 3 mm long and 0.5 mm wide patterned using an excimer laser. Transport critical current density (J_c) measurements were made at 77K using the 4-probe method and a 1 μV/cm criterion.

The superconducting transition temperature (T_c) was measured using an ac susceptibility technique with the amplitude of the magnetic sensing field, *h*, varied from 0.025 Oe to 2.2 Oe at a frequency of approximately 4 kHz [1,5]. Samples were mounted onto the end of a sapphire rod and measured as the sample temperature increased through the transition region at very slow rate (~ 0.06 K/min). The ΔT, or temperature spread, between the temperatures at which the maxima in the ac loss occurs for the 0.025 and 2.2 Oe applied magnetic fields (peak to peak of χ") was determined. In addition, the full-width at half-maximum (FWHM) of the χ" vs. T width (ΔT) of the loss component of susceptibility data was determined separately for the individual 0.025 Oe magnetic field data and the 2.2 Oe magnetic field data for comparison.

RESULTS AND DISCUSSION

Measured T_cs of the samples were generally 90-92 K for the YBCO samples and 88-90 K for the Y123/Y211 composite films as determined from ac susceptibility measurements. Thicknesses of the samples ranged from 0.2 – 1.0 microns. Transport current densities varied and are displayed in the figures below vs. ΔT, the temperatures at which the maxima in the ac loss occurs for the 0.025 and 2.2 Oe applied magnetic fields (peak to peak of χ"). Figure 1 shows data for standard YBCO films and Figure 2 shows data for the Y123/Y211 composite films. In general, the temperature spread between the ac loss data for the different applied magnetic fields increases as the critical current density of the films decreases. Even so, the scatter of the data points indicates that this is more a general rule of thumb as opposed to a precise and rigid correlation.

Of interest is that there are two "tails" in the figures in which the data either slowly degrades in J_c as the ΔT broadens or rapidly drops in J_c as the ΔT slightly increases. As seen in Figures 1 and 2, these "tails" can be separated out by the T_c of the samples. It is found that chosing a

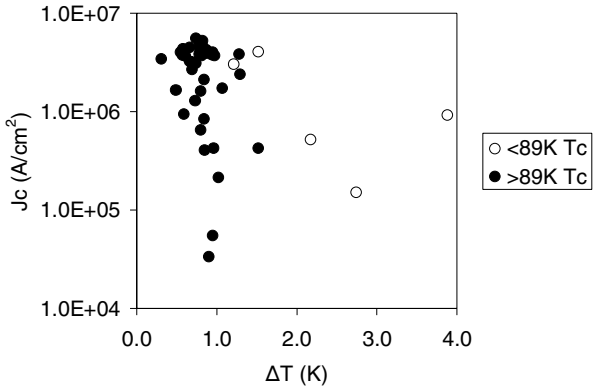

Figure 1. Transport J_c vs ΔT for YBCO films

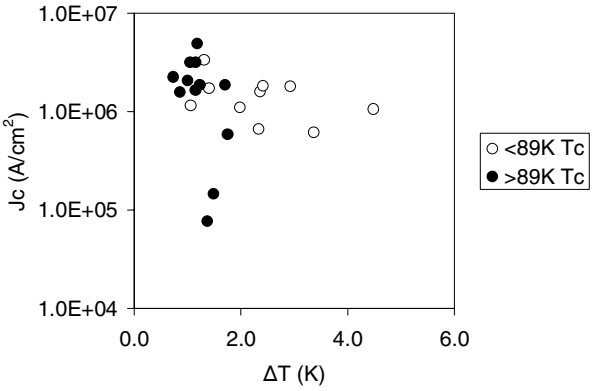

Figure 2. Transport J_c vs ΔT for Y123/Y211 composite films.

A value of 89 K best separated the two. The data points were also identified by thickness of the sample to observe any effect this might have had on the susceptibility data, but no obvious correlation to thickness occurred. The relationship of the data to T_c in the figures may be strongly influenced by the data being taken near the critical transition temperature. Further, the data points with a narrow ΔT and yet very low J_c, the bottom of the rapidly falling "tail," can result from microstructural defects in the film or improper phase formations. These defects can lower the transport current density across the length of the film and yet locally across the film remain high. In one of the samples in this category a crack in the film was observed, but it was not clear for the others samples. Additional work will be required to determine this.

CONCLUSIONS

A detailed study was performed on YBCO films and Y123/Y211 composite films produced by pulsed laser deposition to study the correlation between film quality and ac loss data from magnetic susceptibility measurements. There appears to be a general correlation that as ΔT widens between the temperatures at which the maxima in the ac loss occurs for 0.025 and 2.2 Oe applied magnetic fields (peak to peak of χ''), the film's associated J_c decreases . The correlation is stronger than the association with the full-width at half-maximum (FWHM) of the χ'' vs. T width (ΔT) of the loss component of susceptibility data as determined for the 0.025 Oe magnetic field data and the 2.2 Oe magnetic field data. Uncertainty in the strength of the correlation is caused by the second "tail" in the data which does corresponds to the relative T_c but cannot be fully explained. Although not clear, this may result from the YBCO film and Y123/Y211 composite film still being of good quality but having lower transport J_c due to blockages of the transport current path from microstructural defects, phase impurities, etc. A correlation on this level may prove useful as a preliminary screen of HTS film quality, especially as good HTS films can now be routinely made.

ACKNOWLEDGMENTS

The authors acknowledge the Air Force Office of Scientific Research and the Air Force Research Laboratory for funding of this project. We also thank Julianna Evans and Kerry Fields for assistance in measuring the properties of the films.

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